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ANALYSIS OF THE WIND-FIELD PATTERN IN CYCLONES, USING TELEVISION PICTURES OF CLOUD COVER TAKEN BY THE "COSMOS-122" SATELLITE

A. I. Burtsev, T. P. Popova

and

L. A. Anekeyeva

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ANALYSIS OF THE WIND-FIELD PATTERN IN CYCLONES, USING TELEVISION PICTURES OF CLOUD COVER TAKEN BY THE "COSMOS-122" SATELLITE

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ABSTRACT. The structural features of cloud fields in two cyclones with fields of vertical air velocities and streamlines are compared. /69*

The vertical velocities were calculated on a seven-level model [1]. It was shown that the isolines of zero vertical velocities in the lower half of the troposphere generally follow the cloud spirals and the frontal cloud bands, consisting mainly of stratiform clouds. The development of a field of vertical movements in the cyclone is traced: gradually descending movements from the rear of the cyclone are distributed behind a cold front into the southern and central parts of the cyclone. The development of the cloud spiral also follows the development of the vertical velocity field.

The system [3] for calculating the real distribution of the wind in the atmosphere was used to plot the streamlines. It is shown that the cumuliform clouds in the frictional layer are arranged along the streamlines converging on the center of the cyclone. Above the frictional layer, there arises a single spiral of stratiform clouds, all circling the center of the cyclone. It is pointed out that the zone of partly cloudy weather between two cyclones coincides with the lines of convergence of the streamlines, clearly visible at the 500 mb level. 4 Illustrations, 5 Bibliographical References.

The development of artificial Earth satellites has opened up new pathways for the study of atmospheric processes and the improvement of methods for analyzing and forecasting the weather. Television cameras mounted aboard satellites allow a survey of cloud cover over territories which are commensurate with important synoptic objects. Unlike discrete observations made from

* Numbers in the margin indicate the pagination in the original foreign text.

the ground, photographs of cloud cover obtained from satellites have provided a clear picture of the cloud systems of cyclones and atmospheric fronts as a whole. In addition, photographs of cloud cover made by television cameras with sufficiently high resolution reveal structural details of cloud fields which it would be theoretically impossible to obtain with the aid of ground observations, even in regions with a dense network of meteorological stations. This feature of satellite observations of cloud cover allows additional information to be obtained regarding atmospheric parameters which are presently not being measured from satellites. Such data are important primarily for the analysis of atmospheric processes above regions with a sparse network of meteorological stations. Even in those areas where this network is sufficiently dense, however, the intermediate features of cloud fields that appear in television pictures can be of significant assistance in analyzing a synoptic situation.

Data from satellite observations of cloud cover found applications in the operational activity of many forecasting sections immediately after the launching of the first meteorological satellites. A number of interesting studies have been made thus far regarding the interpretation and utilization of television pictures of cloud cover. Satellite meteorology is still in its infancy, however, accumulating facts and analyzing some of them. An extremely interesting experiment is one involving photography of the cloud cover and measurement of the components of the Earth's radiation balance using the Soviet "Cosmos-122" satellite. The television apparatus aboard this satellite has provided a great many photographs of the cloud cover above various regions of the globe in different synoptic situations.

One of these series of such photographs is analyzed in this article. We selected as the object of our investigation the cloud systems of two cylcones, one of which was located above the Central Siberian plateau when it was photographed from the "Cosmos-122", while the other was above the West Siberian /4
lowlands (Figure 1). The television picture of the cloud cover in the vicinity

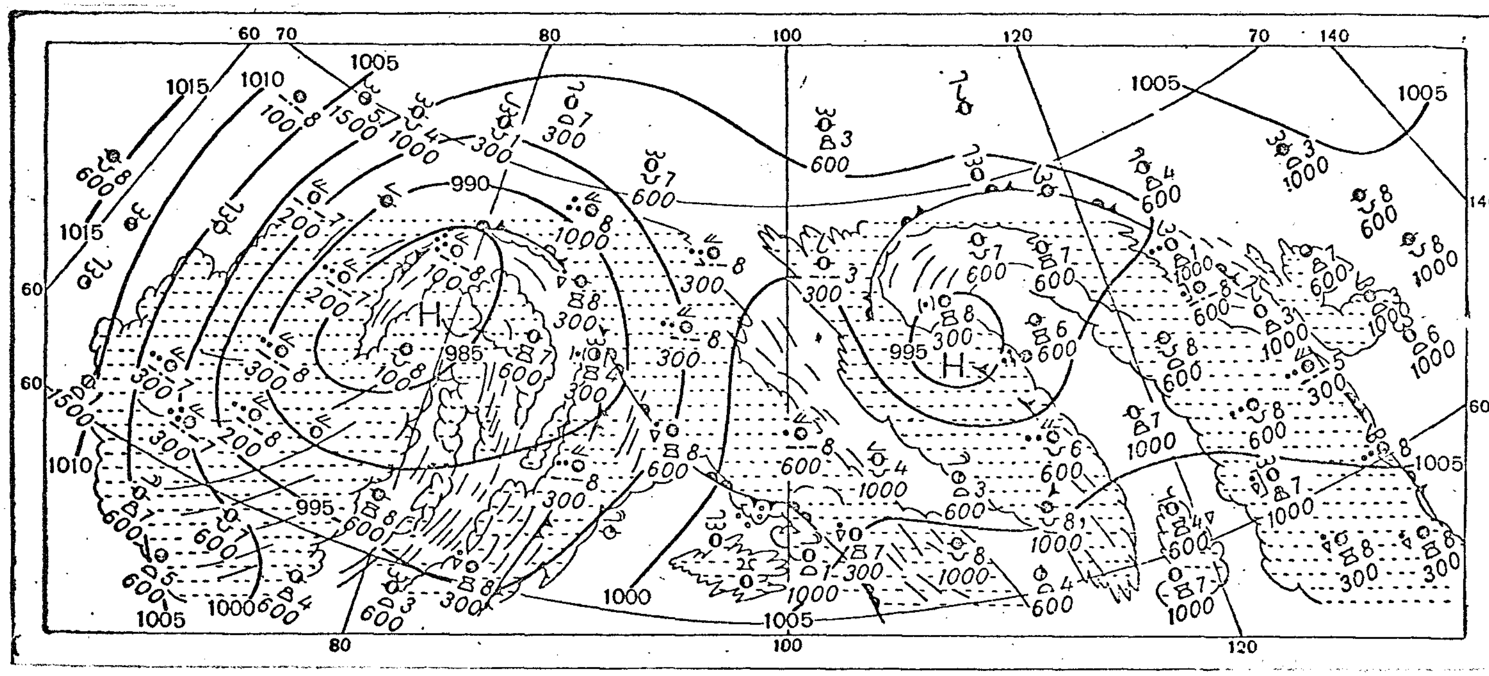

Figure 1. Synoptic chart for 0600 hours (Moscow time), 25 July 1966 and the pattern of the cloud cover as indicated by satellite.

of these cyclones, shown in Figure 2, provides a clear idea of the structure of the cloud field in different parts of the cyclones [2]. The cloud systems of the warm and cold fronts of the cyclone above the West Siberian lowlands (left side of the picture) appear in the photograph as wide bright bands, located at A and B, respectively. At C these bands blend into a single band which envelops the cyclone in a spiral along its eastern, northern and western edges. The dark portion of the picture (area D), bounded by the two above mentioned bright bands, corresponds to the partly cloudy warm sector of the cyclone. The uniform appearance of the picture in the northern part of the cloud spiral (area E) indicates that stratus clouds occur in this part of the cyclone. The data from ground observations indicate that these are As-Ns clouds, from which there was scattered precipitation. Judging from the picture, the southern part of the spiral (area F) consists of higher and thinner clouds. The banded structure of the cloud cover is quite evident here. In area G we can see cumuliform convective clouds, forming banks which converge in spirals on the center of the cyclone, forming a cloud vortex at point 1. At the time it was photographed, this cyclone was already a high baric formation. It was in an occluded state, but the thermal asymmetry was already quite advanced. At ground level, in the southeastern part of the cyclone, there was still a warm sector bounded by the cold and warm fronts whose cloud systems are clearly evident in the television pictures.

The cloud system of the cyclone above the Central Siberian plateau (right side of the picture) consists of a broad band of clouds enveloping this cyclone in a sprial along its eastern, northern and western edges. Within this gigantic spiral (area O) we can see banks of low cumuliform clouds which converge on the center of the cyclone near the ground at point 2, forming a cloud vortex. The uniformity of the picture of the cloud band at the eastern edge of the cyclone (area J) indicates that the clouds in this part of the cyclone are primarily stratus. The cloud band narrows significantly at the northern edge of the cyclone (area K); the surface of the Earth is visible between the individual cloud formations. The western part of the cloud spiral (area L) consists of clouds on two levels. Here the convective clouds of the rear of the

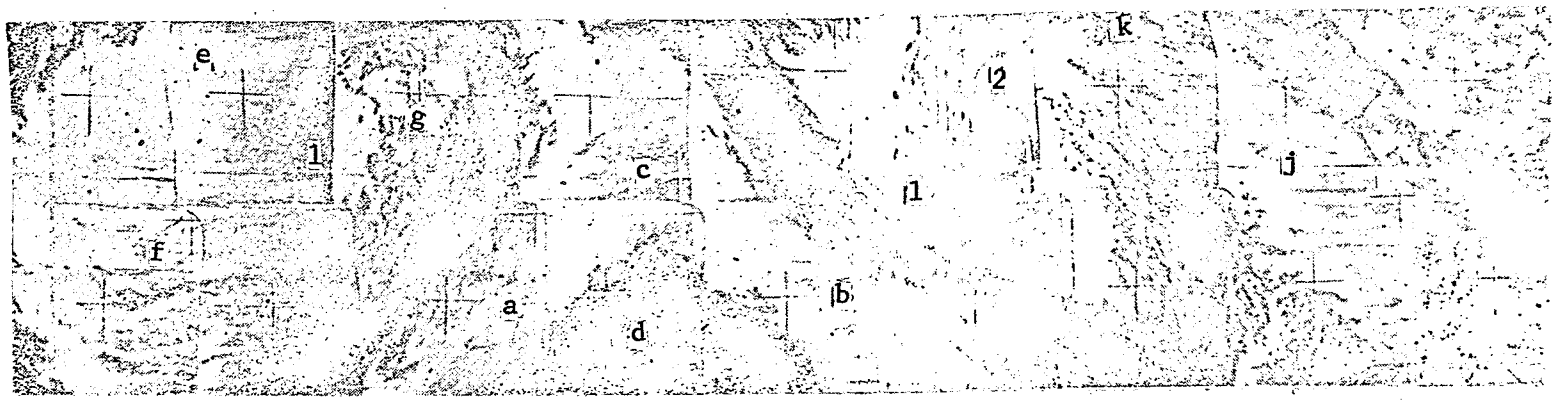

Figure 2. Television picture of clouds, produced by "Cosmos-122" satellite: 25 July 1966, 0707 hours (Moscow time).

cyclone can be seen at some places through the comparatively thin clouds at the middle and upper levels. A second cloud vortex appears at point 3.

Data from ground observations and temperature-wind soundings indicate that the cyclone is already occluded. It has almost been pinched off at the bottom, becoming an individual cyclone in the trough of the deeper cyclone above the West Siberian lowlands. A clearly pronounced closed cyclonic circulation of the air is still retained in the upper and middle troposphere.

The investigations that have been performed so far indicate that the macro- and mesoscalar features of cloud fields are closely related to the wind field streamlines. It would be interesting in this regard to compare the structural features of the cloud fields described above in these two cyclones with the field of vertical velocities of the air and the wind-field streamline patterns.

Figure 3 shows charts of the vertical velocities at the 775, 600 and 400 /7
mb levels, calculated with a seven-level model [1]. If we compare the distribution of vertical velocities at these levels with a cloud-cover chart, we will see that the isolines of zero vertical velocity in the lower half of the troposphere follow the cloud spirals and frontal cloud bands quite closely. The latter consists mainly of stratiform clouds. Several features of cloud structure in individual parts of the cyclones are also reflected in the field of vertical velocities.

Note that the distribution of vertical velocities in both cyclones, at different stages of development, agree with the typical distribution of the vertical velocities in cyclones which was given in [4].

In the left-hand cyclone, which is in an occluded state, the distribution of vertical velocity indicates a process of development still in progress. The focus of ascending movements, located in the lower layer of the troposphere near the center of the cyclone, shifts to the forward part with height. The rate of ascending movement increases with height, reaching a

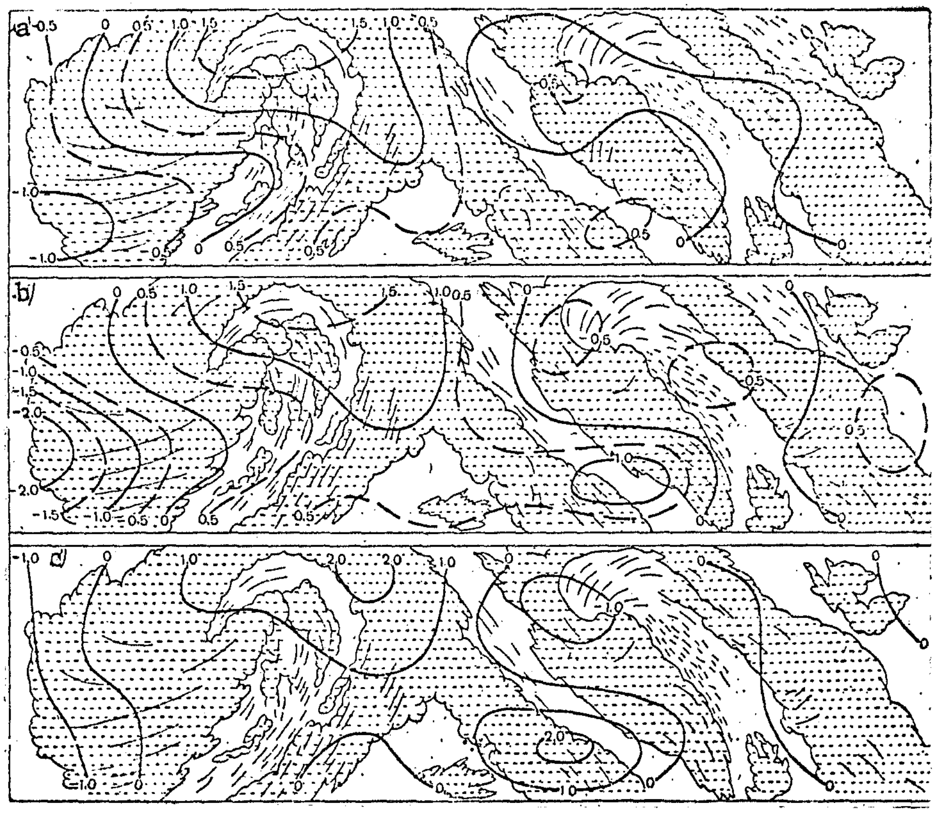

Figure 3. Distribution of vertical velocity (m/sec) at 0300 hours (Moscow time), 25 July 1966. (a) At the 755 mb surface; (b) 600 mb (c) 400 mb.

maximum at a height of approximately 7 km. At this height, the position of the center of the focus of rising movement coincides with the position of that part of the cloud spiral composed of stratus clouds that have undergone considerable vertical development.

The area of descending currents in the lower half of the troposphere is at /8 the rear of the cyclone, in its southwest sector. Degenerate stratiform clouds remain here only in the upper half of the troposphere, while an intensive development of acumuliform convective clouds is observed below.

It should be mentioned that, although the zero isoline of vertical velocity generally follows the configuration of the cloud sprial, we have not observed complete coincidence of the limits of the bands of stratiform clouds and the isolines of vertical speed, as we would expect. This failure to agree is most markedly visible in area G, where cumuliform clouds of convection occur in a region of rather considerable ascending movement. Convective clouds also appear in regions with descending ordered movement, which agrees with the results obtained in [5]. The speed of the convective currents formed in unstably stratified cold air is an order of magnitude greater than the speed of the ordered ascending currents that arise due to transient conditions. The superposition of certain vertical currents on others creates a complex field of vertical velocity with considerable horizontal gradients. This is also reflected in the structure of the cloud cover. At area G in the picture we can see the accumulation of large cumuliform clouds. Although the clouds are rather randomly distributed, we can see a light tendency toward a spiral curvature even here. Somewhat to the south, where the ordered ascending currents slacken and convection is of prime importance, the bands of cumuliform clouds have a more correct sprial shape.

The isolated focus of ascending currents in the southern part of the warm front indicates a process of wave formation in this front. A weakly formed wave at this location turned into a small but clearly evident cyclone in the days that followed, with a characteristic spiral structure of the clouds.

The distribution of the vertical velocity in the right-hand, already occluded cyclone indicates its having been pinched off. The motion is descending in the entire central portion of the cyclone. The weak rise of air is observed only at the south eastern edge. Here, however, the cloud spiral has its minimum width and consists of clouds that extend a considerable distance vertically. A process of scattering and erosion of the clouds is evident in the other parts of the cloud sprial.

The distribution of vertical velocities at the 775 mb level indicates that the movement is descending in the lower layer of the troposphere inside the cloud spiral, where only cumulus and altocumulus clouds are seen.

Using the example of these two cyclones, we see the evolution of the field of vertical currents in the cyclone in the course of its development. The gradually descending currents from the rear of the cyclone spread out behind the main cold front into its southern and central parts. The development of the cloud spiral also proceeds in accordance with the development of the field of vertical currents.

In addition to the vertical component of air currents, another important characteristic of the field of wind currents is the wind-field pattern. A comparison of the wind-field pattern with the baric field will show that all well-developed cyclones have their wind-field patterns arranged in vortices. An analysis of a great many pictures of the cloud cover, obtained from satellites, will show that the direction of the spiral cloud bands in the cyclones corr-esponds with the direction of the wind-field pattern at those heights at /9
which the clouds are located. The wind-field pattern spirals depend on the characteristics of the flow field. The wind-field patterns for the cyclones in question at three levels (frictional layer, 500 and 300 mb) are shown in Figure 4.

To plot the wind-field patterns in this paper, we have used a system [3] which takes into account the actual wind distribution in space. The plane wind-field patterns were calculated on basic isobaric surfaces.

In both cyclones, the wind-field pattern converges in spirals on a single point, the point of convergence, which coincides with the center of a cyclone near the ground.

In the right-hand cyclone the banks of low cumuliform clouds behind the cold front are arranged along these wind-field patterns. In the zone of the cold front, currents of warm and cold air converge along the lines of convergence.

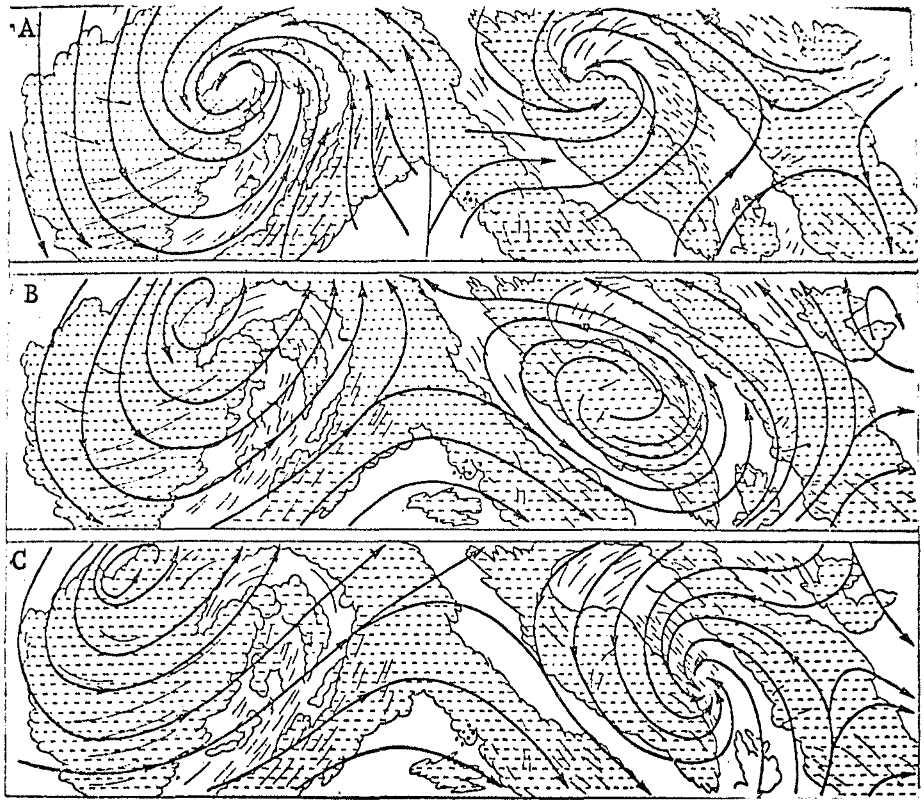

Figure 4. Wind-field pattern streamlines at 0300 hours (Moscow time), 25 July 1966. (a) in frictional layer; (b) at the 500 mb surface; (c) 300 mb.

In the left-hand cyclone, in the vicinity of the center near the Earth, we can also see banks of cumuliform clouds arranged along the lines of convergence in the frictional layer.

The directions of the lines in the wind-field pattern change with height in both cyclones. The convergence of the wind-field pattern on the centers of the cyclones is retained at the 850 and 700 mb levels. At the 500 mb level, however, we can see a clearly pronounced divergence of the wind-field pattern lines with retention of cyclonic curvature. The point of divergence of the wind-field pattern streamlines in both cases coincides with the center of the /10 cyclone at this level. The curvature of the western arm of the cloud spiral in the right-hand cyclone and the formation of a second cloud vortex are the result of air circulation at a height of 5 to 6 km near the upper limit of the clouds forming this arm of the spiral.

The cloud bands, consisting of middle-level clouds, are located approximately along the wind-field pattern lines at the 700 and 500 mb levels.

Our attention is drawn to the existence of a divergence of the wind-field pattern lines near the point of occlusion in the left-hand cyclone. The same divergence is seen in the right-hand cyclone at the south eastern edge. Here it is already difficult to trace the point of occlusion, since the occlusion process is practically complete already. A warm trough is still extant at high levels, however.

The area of partly cloudy weather between two cyclones coincides with the lines of convergence of the wind-field pattern; this is especially evident at the 500 mb level.

The direction of the wind-field pattern streamlines in cyclones changes once more in the layer from 500 to 300 mb. At the 300 mb surface, the streamlines again converge on the centers of the cyclones at these heights. The zones of divergence at the peak of the warm trough at the point of occlusion are retained at this surface, and the zone of convergence between the two cyclones is also retained.

The bands of high clouds located in the upper half of the troposhere in the left-hand cyclone are oriented along the streamlines at the 300 mb surface.

Note the existence of significant differences in the structure of the streamlines in the wind-field pattern at the isobaric 300 mb surface in both cyclones. If the streamlines in the right-hand cyclone constitute a family of spirals converging on one point, similar to the spirals in the frictional layer, the streamlines in the left-hand cyclone will form one continuous spiral.

The structural differences in the streamlines in the cyclone will also cause differences in the structure of the cloud spirals. The banks of cumuliform clouds in the frictional layer constitute a family of spirals converging on one point. Above the frictional layer, one common spiral of stratiform clouds converging on the center develops in the cyclone.

If the streamlines in the wind-field pattern have the form of a family of spirals even in a free atmosphere, the cloud bands will obviously be identical to them.

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